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June 9, 2020

Melissa Sikes
Technical Administrator
Arizona Department of Water Resources
1110 West Washington Street, Suite 310
Phoenix, AZ 85007

RE: AMWUA Water Loss Control Technical Assistance & Training Program – Task 4 Complete (ADWR Contract 2019-3077)

Dear Ms. Sikes,

The Arizona Municipal Water Users Association (AMWUA) is pleased to inform you that Stage 3 of the AMWUA Water Loss Control Technical Assistance & Training Program (Program) has been completed. Since our last submittal in January, four virtual trainings have been held for the participating utilities on the subject of water loss economics, water loss control software resources, and next steps for sustaining water loss control programs in-house. In addition, the AMWUA members continued to receive technical assistance provided by the Southwest Environmental Finance Center (SW EFC) as well as individualized recommendations for water loss control strategies tailored to each utility.

Completion of Stage 3 marks the end of the Program's structured training and technical assistance, though the SW EFC remains engaged and available for Program participants seeking further guidance. At this time, we will be turning our sights towards compiling and analyzing the results of the Program over the past 18 months and development of a final report describing Program outcomes and potential next steps. We are eagerly looking forward to evaluating and communicating the results of the Program as a whole.

Please accept this submission as the Task 4 Deliverable pursuant to Contract 2019-3077. Also included is a "Stage 3 Progress Report" with more detail on the Program accomplishments to date, and an accompanying invoice. We greatly appreciate the opportunity to administer this Program as a result of ADWR's funding and collaboration. Please do not hesitate to reach out if you have any questions or comments.

Best,

Patrick J. Adams
Program Administrator

AMWUA Water Loss Control Training and Technical Assistance Program
Stage 3 Progress Report

Submitted to
Arizona Municipal Water Users Association

Submitted by
The Southwest Environmental Finance Center
Center for Water and the Environment
at The University of New Mexico

Program Funding provided by
Arizona Department of Water Resources

June 3, 2021

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Executive Summary:

The Southwest Environmental Finance Center (SW EFC) at the University of New Mexico's Center for Water and the Environment contracted with the Arizona Municipal Water Users Association (AMWUA) to develop and provide a Water Loss Control Training and Technical Assistance Program (Program) to the AMWUA member utilities through a Sponsored Research Agreement dated January 30, 2020. Funding for this program was provided to AMWUA by the Arizona Department of Water Resources.

The AMWUA member utilities participating in the Program serve over 3.6 million people in the most densely populated portions of Arizona. The State of Arizona and the AMWUA Members are keenly aware that water is a precious and limited resource in the desert Southwest. Though the state of Arizona requires utilities to limit "lost and unaccounted for" water below a 10% threshold, the state's reporting requirements do not conform to industry standards and do not have a data validation component. Further, the state reporting requirements focus on real losses, but do not include an industry standard analysis of sources of loss, types of loss, losses classified as apparent loss, or an evaluation of water loss economics.

The Water Loss Control Training and Technical Assistance Program is designed to address these gaps by focusing on development and/or expansion of the AMWUA member utilities' internal capacity to document, evaluate, and address real and apparent water losses. This will be accomplished by using the industry-recognized and approved best management practices of the American Water Works Association's (AWWA) M36 methodology.

Prior utility experience with the M36 methodology varies, with some AMWUA member utilities having had M36-based water audits completed prior to this Program's initiation and others having never engaged with the AWWA's M36 methodology or software. The Program is therefore designed to meet each AMWUA member utility where they are and to build on and enhance existing water loss control efforts by equipping them with the knowledge, skills, and experience necessary to implement the M36 water auditing methodology, including the methodology's more advanced practices, beyond the duration of the Program.

Stage 3 of the program's training focused on water loss economics, advanced water loss analysis, and developing internal water audit and water loss control processes. Technical assistance was tailored to specifically address the individual needs of each utility as identified in the Level 1 Validation findings and activities undertaken during earlier Program stages. SW EFC staff coordinated with the staff of each AMWUA member utility to determine what water loss control areas they wanted to focus on during Stage 3. SW EFC staff endeavored to meet each utility "where it was in the process" and to address the Water Loss Control issues that each utility deemed most important, urgent, or appropriate.

All 9 AMWUA member utilities participated in training and engaged SW EFC staff for technical assistance. Though Covid-19 restrictions, personnel changes and conflicting priorities

continued to pose some challenges, all of the participating AMWUA member utilities showed progress in deepening their understanding of water auditing and water loss control techniques. Further, all of them were able to demonstrate positive outcomes from the practical application of Program learnings and the analysis of their own data, policies, practices, and procedures in a water loss control context. These outcomes include, among others, improved audit accuracy, reduced real losses over prior years, and the development and implementation of a large-scale data collection and warehousing initiative to facilitate improved water loss control efforts and analysis. These Program successes and others are discussed further in the main body of this Report, as are the details of Stage 3 training and technical assistance activities.

Section 1: Summary of Accomplishments and Challenges

Summary of Accomplishments

While Stages 1 and 2 of the Program focused on the water auditing process using the American Water Works Association's (AWWA) Water Audit Software (WAS), as well as validating, refining and interpreting water audit results, in Stage 3 the Program's focus was loss economics, advanced water loss analysis, and developing internal water audit and water loss control processes. The Program's series of virtual trainings continued, but the major emphasis in Stage 3 was tailored, utility-specific technical assistance. The AMWUA member utilities were individually contacted to identify the specific areas they wanted to focus on in Stage 3.

The Stage 3 training activities were designed to explore and provide in-depth understanding of:

- The economics of leak detection and the use of longitudinal data to guide leak detection efforts;
- AWWA's software changes and the implications of using the new version 6 of the software in future audits; and
- Promoting the long-term viability of Water Loss Control Programs and institutional knowledge retention through the documentation of practices, processes, and procedures related to water loss control activities including, but not limited to, water loss auditing.

A list of Stage 3 trainings is provided in Table 1 below; they are described in more detail in Section 2 of this report.

Table 1: Stage 3 Training Activities

Task	Date Completed	Attendance*			
		Number of Utilities Represented (of 9)	**AMWUA Member Utility personnel attending**	**Non-utility personnel attending** (AMWUA; ADWR)	**Total attendees**
Economics of Water Loss Virtual Training	March 4, 2021	9	30	1	31
AWWA v6 Water Audit Software Changes (Optional)	March 29, 2021	5	8	1	9
Cases Studies with AMUWA Utilities & Developing your Water Audit SOP	May 3, 2021	9	34	4	38
Using Power BI Software to Present Water Loss Data	May 26, 2021	9	23	1	24
*Attendance numbers do not include SW EFC team members					

High levels of participation continued in Stage 3. All nine of the participating AMWUA member utilities attended training sessions and each utility also received:

- Individual Economic Level of Loss (ELL) curves tailored to their utility using available data to help guide future leak detection efforts;
- a copy of the ELL spreadsheet tool to generate additional ELL curves in the future;
- a 2019 water audit developed using the newly released v6 WAS with an explanation of differences in results from version 5 of the WAS; and
- a Water Loss Audit Guidance document based on their Level 1 Audit Validation that can guide future audits and ensure consistency from year to year.

SW EFC staff also continued to engage with the participating AMWUA member utilities providing technical assistance on a variety of topics including, among others:

- Refinement of 2019 water audit data and grading validation;
- Main break data analysis;
- Production and customer meter testing;
- Leakage component analysis;

- Leak detection; and
- Field data collection and data warehousing options.

During Stage 3 the participating AMWUA member utilities continued to use the knowledge developed in the Program to spur water loss control related action. Some examples are described below.

- One utility applied the knowledge gained during the Program to its 2020 State water loss reporting and recorded the lowest lost and unaccounted for water percentage it has seen in recent years.

- One utility used the water auditing techniques learned in Stages 1 and 2 to perform a "mini-audit" on a system that serves reclaimed water to a handful of customers and sends the excess to a Salt River Project (SPR) underground storage project. The utility determined that the meter counting water received by the underground storage project was underreading significantly and that, as a result, the utility was missing out on valuable long-term storage credits that are essential to that utility maintaining a renewable supply during times of drought and shortage. The utility then worked with SPR to develop a procedure for routine meter calibration.

- One utility discovered through investigation of its water audit results that it had been double counting a volume from its own sources. This discovery will lower its reported real loss volume on future water audits and state water loss reports.

- Two utilities provided data to initiate Leakage Component Analysis and Break Rate Index analysis. While both utilities' analysis confirmed low overall main break rates when compared to published AWWA standards, one member utility's data showed a PVC main break rate significantly higher than the US/Canadian average, providing a focus area for future water loss control investigation.

- Two utilities identified well purge data as an area for investigation. One member utility identified several wells that need excessive purging before producing treatable water. That member utility is analyzing data and implementing a well optimization program to reduce non-revenue water (NRW) from such excessive well purging. The other member utility has focused on documenting the locations of well purge meters relative to production meters to ensure that purge and production volumes are accurately counted and categorized.

- Several utilities are reviewing production and consumption meter testing processes and programs, and one member utility is developing and implementing a multi-year wellhead meter testing and calibration program to minimize future production volume errors.

- One utility continued the investigation and assessment of a poorly designed and installed potable production master meter at its water treatment plant that began during Stage 2 of

the Program. Over-registration was confirmed, and a replacement master meter and housing have been budgeted.

- In one utility where water that is flushed to improve quality was typically sent to a storm sewer and discharged without credit, field operations crews have identified key areas where such flushing volumes can be diverted into the sanitary sewer for recovery as treated effluent and plans to implement this operational change are currently being developed.

- In preparation for adding a new water source to its distribution network, which will change water flow patterns, one utility identified areas where water losses from flushing can be reduced by using No-DES's recirculating/filtering process through hydrants, instead of simply flushing to drains. The utility has entered into a contract for such services in those areas. Another member utility is investigating whether this method might be advantageous for them.

- Several utilities have contracted for leak detection to further pinpoint undetected main and service line leaks and are collecting the resulting leak data for future analysis. To reduce excessive consumption and build customer good will, one of those member utilities is notifying its customers of any leaks discovered on the customer-owned portion of service lines.

- One utility is performing a form of post-audit component analysis by testing a cohort of AMR meters that are currently being replaced to determine whether their 2019 water audit meter correction input was reasonable.

- Several of the utilities used the discovery of data gaps that hampered or precluded higher level analysis, as a springboard for further investigation and change. In several cases this has spurred internal discussion about replacing manual data collection and storage activities with systematic electronic data collection and maintenance processes. SW EFC staff facilitated some of these discussions with presentations examining utility field data collection software and how collected field data can be integrated into GIS and other software for analysis. In response, one of those member utilities is currently developing a large-scale data collection, warehousing, and reporting program that will streamline operations, eliminate many manual procedures and enable the development of accurate and complete data sets for future analysis, and another member utility is communicating with them to determine whether to implement a similar program.

- Two utilities identified certain treatment plant operations that used poorly quantified volumes of unbilled unmetered water and made them a focus for further investigation. One plans to also improve data collection and storage procedures for flows such as: line flushing, firefighting, street cleaning, and maintenance uses.

- Several utilities continued to refine their 2019 Water Audits.

- One utility that has begun the 2020 audit process is deciding if it is best to use Version 5 or 6 of the WAS. They also have realized they have data available for the "unbilled unmetered" volumes and can move away from using the default. This will improve the accuracy of the audit and provide more detailed information to the utility moving forward.

- At the conclusion of the Economic Level of Loss training session, the SW EFC facilitated a peer-to-peer discussion. During the discussion one member utility wanted to determine if it was economical to reinstate their program of testing customer meters using their own test bench. The discussion led them to consider some data analysis to determine if it is economical to redeploy the test bench. The overall conclusion was that it is very likely worthwhile to reestablish the testing program rather than replace meters on a 10-year cycle.

Challenges

While program success continued during Stage 3, balancing Program participation with other utility priorities has remained an ongoing challenge for some AMWUA member utilities. Continued COVID-19 restrictions required the Program to remain entirely virtual. Stage 3 also coincided with Arizona's state water loss reporting window. Therefore, many of the AMWUA member utilities, of necessity, focused their efforts during the first half of Stage 3 on state reporting requirements.

For one utility, specifically, the lack of internal communication and willingness to provide data has left the utility with a lower validated data validity score than is likely necessary. This member utility's water loss control team lead and the SW EFC staff lead have attempted to communicate with utility managers on multiple occasions without success. The utility has decided they will have to accept the lower data validity grade and work on improving internal communications in the future.

Personnel changes continued in Stage 3. This left some AMWUA member utilities temporarily short-handed and required that replacement staff be brought up to speed on the Program. Some higher-level analysis was hampered by a lack of utility data, and in some cases an inability to prioritize providing such data to SW EFC staff. Less effective lines of communication also remain an issue. Some AMWUA member utility Water Loss Control teams did not meet regularly during Stage 3, and some did not engage with SW EFC staff beyond attending trainings and email communications. Finally, some water loss control teams were not given timely updates about utility water loss control activities such as leak detection and meter replacement.

Despite these challenges each participating AMWUA member utility remained engaged during Stage 3. Progress continued and the knowledge gained during Stages 1 and 2 of the Program continued to have a positive impact on the AMWUA member utilities during Stage 3.

Section 2: Description of Stage 3 Activities

Economics of Water Loss (webinar)

On March 4, 2021, SW EFC staff presented the Economics of Water Loss Virtual Training. This training covered water loss economics in the water auditing context, reinforcing the fact that losses cannot be reduced to zero and demonstrating that every AMWUA member utility has a threshold real loss level below which the costs associated with loss controls exceed their benefits. The webinar had 31 attendees. All 9 participating AMWUA utilities were represented. In this webinar SW EFC staff:

- explained the Economic Level of Leakage (ELL) concept;
- discussed the theoretical vs practical ELL applications;
- compared and contrasted the use of ELL and Component Analysis techniques to drive water loss control and other operational actions; and
- demonstrated how a utility can frame leak detection efforts using the ELL in conjunction with water audit results, with an emphasis on optimizing those efforts through data collection and reducing diminished returns that result from over-aggressive leak detection programs.

This webinar ended with an optional, 1-hour, SW EFC-moderated, peer-to-peer session. Staff members from Peoria and Avondale attended this optional session where topics discussed included:

- the development and maintenance of source and customer metering programs; and
- CMMS systems

ELL Curves & Spreadsheet Tool

To supplement the Economics of Water Loss Virtual Training, SW EFC used its own spreadsheet tool to develop preliminary ELL curves for each participating utility using available data. ELL curves graphically represent the most economical level of distribution system-wide leak detection effort if the underlying assumptions are accurate. Individual ELL curves were provided to each AMWUA member utility with a copy of the ELL spreadsheet tool for future use. While the ELL curves provided are preliminary, they indicate that the resources each AMWUA member utility should devote to leak detection efforts may vary considerably and should be based on their particular utility size, recoverable real loss volumes, water value and the costs associated with leak detection and repairs. These curves (which are included in the digital SharePoint supplement to this Report) can continue to be refined by the participating utilities as additional data becomes available.

AWWA v6 Water Audit Software Changes (Optional Webinar)

The AWWA released version 6 of the AWWA WAS (WAS v6) near the end of Stage 2 of the Program. This update, while a significant improvement over WAS v5, included calculation changes that can produce higher Real and Apparent Loss volumes, and lower Unbilled Unmetered consumption volumes when compared to WAS v5. The participating member utilities used v5 to develop their 2019 water audits. Additionally, changes in the WAS v6 data grading process, grading criteria and available individual data grades can lower overall Data Validity Scores, particularly when audit default values are used.

On March 29, 2021, the SW EFC presented an optional webinar titled "AWWA v6 Water Audit Software Changes" detailing the user interface, data entry and data grading changes in WAS v6. The webinar emphasized that when transitioning to WAS v6, it is important to carefully interpret the audit results, as they may not indicate a worsening of water loss control program effectiveness, but instead simply reflect a change in the WAS itself.

The webinar also covered changes to the WAS dashboard and Key Performance Indicators (KPIs) as the dashboard was redesigned and several of the KPIs used in v5 and its predecessors (e.g., Real Loss as a % of Supply Volume and NRW as a % of Operating Cost) have been removed while several new, normalized KPIs were introduced. This optional webinar was attended by 8 individuals representing 5 of the AMWUA member utilities.

After the webinar, the SW EFC emailed a summary document to each of the member utilities that attended entitled, "V6 AWWA Free Water Audit Software - Summary of Changes from V5." The SW EFC also copied this file into each member utility's SharePoint folders.

2019 v6 Water Audits

As a supplement to the AWWA v6 Water Audit Software Changes webinar, and so that each participating member utility would understand what, if any, impact the v6 modifications would have on their current and future audit results, SW EFC staff recreated each AMWUA member utility's 2019 Water Audit using the WAS v6. In this manner, the SW EFC developed a preliminary data validity score, and drafted a memorandum comparing the results with the WAS v5. An example of the impacts these changes had is shown in Table 2. The changes for each system are provided in the supplementary documents. It is important to understand that these impacts are entirely the result of changes in how certain WAS values are calculated in v6 vs v5. These changes were explained to the utilities during the webinar and are described below. The calculations change the volumes in some individual categories of non-revenue water but do not change the overall total non-revenue water.

Table 2: Comparison Data for One Utility

Category	V6 (AC FT)	V5 (AC FT)	Change in Volume	Change in Percentage
Non-Revenue Water	3,647.263	3,647.263	0	0
Authorized Metered Unbilled	0	0	0	0
Authorized Unmetered Unbilled	151.921	805.196	-653.275	-81%
Total Authorized Unbilled	151.921	805.196	-653.275	-81%
Total Apparent Losses	1073.062	1082.181	-9.119	-0.8%
Total Real Losses	2,422.280	1,759.887	662.393	38%

The method for calculating Unbilled Unmetered volume when the default percentage is used changed from 1.25% of System inputs in v5 to 0.25% of Billed Metered consumption in v6. This change resulted in volumes in this category (unbilled, unmetered usage) decreasing by an average of 82% vs WAS v5 for those member utilities using the default value: Chandler, Goodyear, Mesa, Peoria, and Tempe. Because the *total* non-revenue water volume remains the same in versions 5 and 6, reducing the volume of unbilled unmetered usage means that the volume of real loss must increase. As a reminder, real loss is calculated by subtracting all uses from the total water supplied. If one water use (unbilled unmetered) goes down, another value must increase (real loss) to keep the non-revenue water the same. This change is demonstrated in Table 2. Those member utilities not using the default – Avondale, Glendale, Phoenix, and Scottsdale – had no change in their value of Unbilled Unmetered Authorized Consumption and no resulting increase in real water loss from this change to the audit.

The WAS v6 method for calculating default losses attributable to Systematic Data Handling Errors also changed slightly and lowered the v6 apparent loss volume by an average of 2% when compared to v5 apparent losses. These lowered apparent loss volumes also resulted in a slight increase in real loss calculated by v6 of the WAS, but this change was much less than that described above for unbilled unmetered usage.

While real losses reported using v6 of the WAS were, on average, 17% higher than those reported using v5, and ranging from a low of 1% to a high of 38%, it is important to remember that the *actual* real loss experienced by these systems did not change. The change is only a matter of how the developers of the audit chose to estimate the default values. This change is one more reason that it is recommended that utilities collect their own data rather than using the default; using a system's own data prevents the change in real losses when the audit software is revised.

While the Infrastructure Leakage Index (ILI), one of the reporting metrics, also changed for most systems, the change is generally insignificant and would not alter how this value is interpreted nor would it drive any different actions for any of the utilities.

Additionally, changes in data grading, particularly the reduction of grades associated with WAS default percentages for all three default values from 5 to 3, reduced the Data Validity Scores for most utilities. The decrease is more evident for utilities choosing to use all three defaults than those using one or two and was, on average, 6%. Though the v6 Data Validity Scores have not been fully validated, the changes do not appear significant and would not alter how audit results are interpreted.

Case Studies with AMWUA Utilities and Completing Your Water Audit Guidance Document (webinar)

On May 3, 2021, the SW EFC presented a 2-hour webinar that focused on the development of a utility-specific Water Audit Guidance document and presented a series of AMWUA utility case studies. The webinar had 34 attendees. All 9 participating AMWUA utilities were represented.

This webinar highlighted the importance of formally documenting water loss auditing procedures and responsibilities to foster process improvement, consistency, accountability, teamwork, and knowledge management within a utility that is trying to effectively control water loss. The session explained that the Level 1 Validation report completed for each AMWUA member utility was a starting point for identifying the source of water audit data, potential actions to improve data grades, and suggestions for future actions to improve the audit process. The guidance document is meant to be a living document, revised over time to always reflect the most current processes, while the Validation Report is a historical document that should not be changed once this project is complete.

Because the technical assistance provided to the various AMWUA member utilities during Stage 3 of the Program varied considerably, the second half of the webinar was devoted to sharing case studies of successful activities undertaken by the AMWUA member utilities to encourage further improvements and collaboration in the water loss control arena.

Water Audit Guidance Documents:

In preparation for the above-referenced webinar, individual Water Audit Guidance documents were developed for each participating AMWUA member utility documenting the internal processes each used to develop the 2019 water audit data points to the extent that information was available.

Each Water Audit Guidance identifies: utility justifications for completing water audits and audit boundaries; Water Loss Control Team members; basic water audit concepts; data sources and derivation methodologies for each audit data input and the individuals responsible for providing and/or developing the data inputs; input data grading criteria to be considered; internal and external stakeholders with whom audit results and water loss control results should be shared; and improvements to be made for future audits.

The AMWUA member utilities were then tasked with refining and updating their Water Audit Guidance documents while developing their 2020 water audits so that the Water Loss Auditing processes developed, and institutional knowledge gained during the Program will not be lost.

Using Power BI Software to Present Water Loss Data (Optional Webinar)

This 1-hour webinar was held on May 26, 2021, per the request of the AMWUA member utilities. During the Report Out webinar held in Stage 2 of this program, Scottsdale stated that they were working to move their water audit data into Power BI to facilitate monthly updates and publish outcomes utility-wide. In response, several member utilities expressed interest in understanding how Power BI, or a similar program, could be used to visualize data, and the SW EFC offered to provide such a demonstration to interested member utilities. The demonstration, presented by the staff of EMA, Inc. focused on the data visualization benefits of a program such as Power BI rather than the technical how-to of building a database. The webinar had 24 attendees. All 9 participating AMWUA utilities were represented.

Utility Water Loss Control Recommendation Reports and Updated Level 1 Validations:

As Program technical assistance continues to be delivered, the SW EFC is developing individual Utility Water Loss Control Recommendation Reports containing water auditing and loss control recommendations based on individual Program outcomes for each participating utility. These utility-tailored reports address improvements to policies, practices, and/or procedures that the member utilities can implement to increase the accuracy of future water audits, improve data validity scores, and positively impact future water loss control efforts.

The SW EFC prioritized recommendations to select the most impactful and important in three categories. Water Audit Recommendations focus on the utility's ability to conduct accurate water audits and relate primarily to improving the quantification of losses in their distribution systems. Water Loss Control Recommendations focus on recommendations related to the larger water loss control program and can cover any area or activity. Finally, Program Management Recommendations address the functionality of the utility's water loss control team and internal practices to manage the water loss control program. Implementing these recommendations should improve each utility's ability to quantify and reduce real and/or apparent losses in its distribution system and should positively impact the water loss program and team functionality. The report includes up to three recommendations in each category.

Additional recommendations are also included beyond the prioritized measures described above. While implementing these recommendations could also have a positive impact a utilities Water Loss Control Program, they are less urgent from a loss quantification and reduction perspective.

A sample list of recommendations that will be made on a utility-specific basis is included in the Appendix to this Report in Table A-1 to provide an indication of the types of recommendations that will be made to systems. Please note that this sample list is categorized, but not prioritized. The SW EFC will present each AMWUA member utility with their report prior to the conclusion of the Program. Where 2019 water audits have been amended during Stage 3, updated Level 1 Audit Validation Reports will also be provided.

The Utility Water Loss Control Recommendation Reports will include suggested timelines for audit data collection, preparation, and review to assist the utilities in the timely preparation of future water audits. An example timeline based on a calendar year is included in the Appendix to this Report as Table A-2. Individual timelines will be adjusted to reflect utility operations and audit schedules (fiscal or calendar year).

Summary of Technical Assistance Provided

During Stage 3, the SW EFC continued to provide technical assistance to the AMWUA member utilities. While technical assistance during the first two Program stages focused primarily on water audit development and validation and was therefore somewhat similar from member utility to member utility, Stage 3 technical assistance was tailored to specifically address the individual needs of each utility as identified in the Level 1 Validation findings. SW EFC staff endeavored to meet each utility where it was in the process and to address the Water Loss Control issues that each utility deemed most important, urgent or appropriate.

Three member utilities continued to hold regular weekly or bi-weekly meetings with SW EFC staff, to discuss audit refinement, internal process development and other Stage 3 Water Loss Control topics and activities the member utilities were undertaking. Three member utilities held regular but intermittent meetings with SW EFC staff. Three member utilities only met with SW EFC staff occasionally or maintained communications electronically. Ongoing communication between SW EFC staff and all of the member utilities was also sustained via email.

Thus, while some technical assistance activities (such as ELL, v6 2019 Audit and WAG document development described above), were done with all of the participating utilities, much of Stage 3 technical assistance consisted of consultations regarding specific, individual Water Loss Control and Water Auditing operational process improvements as well as “next level” analysis and activities. In these technical assistance sessions SW EFC staff assisted the AMWUA utilities by:

- Working to improve their 2019 water audit accuracy by refining audit boundaries and inputs
- Working to refine Data Validation Scores by reviewing current relevant policies and procedures as well as suggesting improvements
- Performing leakage component analysis (LCA) to refine categorization of real loss volumes from main leaks, and to assist the utility in understanding data collection requirements for a full mains/service-line/tank overflow LCA

- Performing distribution system infrastructure analysis to identify leak prone pipe materials or diameters
- Developing meter accuracy statistics
- Consulting on production and customer meter accuracy testing programs
- Giving field data collection presentations and demonstrations so that they would better understand how to integrate their field data collection activities with GIS software for visualization and analysis
- Facilitating member utility cooperation on topics such as policy making, NRW reduction and data collection & warehousing techniques.

Section 3: Description of Program Conclusion Activities

Between the date of this Report's submittal and the conclusion of the Program additional activities will occur, including several stakeholder meetings and the submission of final contract deliverables. All remaining items are detailed below.

Water Loss Control Resources:

To supplement the training resources developed specifically for the Program, each utility will be provided access to the SW EFC's Water Loss Switchboard – an online portal that includes a comprehensive collection of Water Loss Control tools and other resources ranging from getting started with water loss control, through performing water loss audits and component analysis, to interpreting water audit results. The Water Loss Switchboard features sections specifically focused on real, apparent, and comprehensive loss controls, and contains a variety of publications and recorded materials developed by the SW EFC and gathered from around the country. These Switchboard resources will remain available to the utilities to help meet their future water loss goals and may be supplemented in the future as new resources become available. The table below summarizes the resources currently available on the Water Loss Switchboard. A full list of the currently available resources is included in the Appendix to this Report as Table A-3.

Table 3: Water Loss Control Resource Summary

Category	Resource Formats	Resource Count
Getting Started	State water loss control manuals; links to AWWA resources, webinar	7
Audit Tools	Spreadsheet tools for developing select water audit inputs, water audit handbook, data grading tools	8

Category	Resource Formats	Resource Count
Component Analysis	spreadsheet and online tools for component analysis; links to AWWA resources	4
Audit Results	Level 1 validation guidance manual; select excel audit data sets; webinar	8
Real Water Loss Control	spreadsheet tools, real loss control guidance documents and webinars	12
Apparent Water Loss Control	pdf tool, guidance documents, webinar	4
Comprehensive Water Loss	Loss control manuals and webinars	6
Presentations and Webinars	North American Water Loss conference presentations, water loss control webinar series, ILI webinar	5

Program Conclusion Meeting

The Program Conclusion Meeting will be held in July, allowing AMWUA member utilities to discuss the benefits of the Program and identify any areas that could be improved upon in the future. At this meeting SW EFC staff will present summary Program statistics and outcomes, identify trends among, and differences between, the AMWUA member utilities, and compare them to national trends.

Program Close-Out

SW EFC staff will close out the Program by presenting program outcomes, benefits, lessons learned, and suggestions for future water loss control activities to various Program stakeholders in a Final Program Report and meetings and/or presentations.
Additional stakeholder presentations may be agreed to at a future date.

Appendix

Table A-1: Sample Recommendations (Note these are general recommendations that are not prioritized

Category	Area	Recommendation
Water Audit Recommendation	Software for future water audits	The SW EFC recommends that the utility perform future audits using v6 of the water audit software. Relative to v5, the data grading process is greatly improved, and the "question and answer" format will permit the utility to better track the reasons for changes in individual data grades over time. Further, v6 uses the most current, industry-standard key performance indicators and contains fields that allow different types and sizes of water system to be easily differentiated. It is likely that as v6 of the WAS is widely adopted, the AWWA water audit benchmarks will become more granular, and the utility will better be able to compare its performance over time with utilities of a similar type and size.
Water Audit Recommendation	File Name Standardization	Consider standardizing file names and formats for water loss audit source data to ensure that year-over-year, and longer time scale analysis can be done on audit data, and the underlying source and summary data. Develop a custody chain and access protocols to ensure that a clean copy of source data and summarized data remains available for future use.
Water Audit Recommendation	Use of WAS Defaults	Use of the WAS default values for the Unbilled Unmetered, Unauthorized Consumption and Systematic Data Handling Error inputs is discouraged when such data can be economically collected and analyzed. While the default values are acceptable when utilities do not have enough information to make a reasonable estimate for these values, using them introduces an unquantified uncertainty into the audit. It is, therefore, recommended that the utility collect data in each of these three areas to compare to the values generated using the WAS defaults on future audits. Note that v6 of the WAS calculates a

		significantly lower value for Unbilled Unmetered volume than v5 and shifts the difference to Real Loss.
Water Audit Recommendation	Production and Consumption Pro-Rating	One of the more difficult aspects of water auditing is adjusting production and consumption data to the designated audit period. When a utility reads meters using multiple cycles the potential exists to accidentally exclude entire days of production or consumption during the audit year, or to include data from the prior audit year because of the way meter reading schedules fall. Under or over reporting production and/or consumption in this manner will artificially inflate or reduce the calculated real loss volume. To avoid this, efforts should be made to pro-rate actual production and consumption volumes and compare the prorated volumes to the straight meter read data to determine whether the difference is significant. If the difference is insignificant these procedures can be dispensed with in future audits.
Water Audit Recommendation	Source and Waste Meter Reading	Manual meter reading procedures are likely to introduce error into volumetric data. If feasible, source meter reading operations should be automated, and a secure data custody chain should be adopted. There are a number of ways that the well meter readings can be automated or partially automated. Ideally, well meters would be fully integrated using a SCADA system and a system of data integrity protocols would be introduced to ensure that any data transmission and/or calibration errors are quickly identified and corrected. Another option is to develop electronic source meter data collection forms using a tablet-based data collection process. Adopting such a procedure, while less ideal than a full SCADA integration, would eliminate the possibility of transcription errors that inevitably arise when paper read records are transcribed into Excel or another digital format.
Water Audit Recommendation	System Storage Tracking	Changes in system storage volume will exaggerate or hide real loss in the audit. Although such volume

		changes are typically small when compared to a year's production and consumption, the volume of water stored in the distribution system at the start and end of the audit cycle should be compared and adjusted for. Major infrastructure changes such as the addition or removal of a storage facility, or the commissioning or decommissioning of significant lengths of new main should be included in this review.
Water Audit Recommendation	Wellhead Meter Testing	When wellhead meters are not regularly tested, the unknown error adds an unquantified level of uncertainty to the audit and makes reasonably accurate meter error adjustments difficult if not impossible. Annual source meter testing is advised. Meters should be tested to ascertain their accuracy at the flow rates they typically operate in (e.g., high and low, or high/mid/low). Longitudinal meter accuracy data should be maintained that includes: • the test date • the testing protocol used • the actual accuracy values at each flow level tested, • whether a meter "passed" or "failed" to meet a specific accuracy standard on initial testing, • where meters initially failed to meet the standard, what action was taken to re-calibrate or repair them, when re-tests occurred, and the re-test results, • where typical flow rates are known, use "run time x flow" calculations to double check that no gross errors are occurring due to malfunctioning meters. All testing records should be maintained so that flow weighted error corrections can be made for the utility's future audits. Procedures should be put into place to ensure that when source meters are taken out of service for repair and the source is still pumping, an as accurate as possible volume can be estimated. Such estimated

		volumes should be clearly identified in volume source data as it should either be categorized as unmetered volume or should be included as an identifiable source volume adjustment.
Water Loss Control Program Recommendation	Leak Detection	While useful information can be gleaned from a full system leak detection effort, the value of reduced losses resulting from such efforts is not likely to be high enough to offset the cost of the detection effort itself. Rather, targeted leak detection is likely to be more cost-efficient and effective. Assuming that audit data is accurate, when the calculated current annual real losses (CARL) is near to or less than the theoretical low-level unavoidable annual real loss (UARL), the utility may be near the lower limit of economically achievable real loss and a system-wide leak detection effort will not result in significant loss reduction. In such cases the standard Economic Leakage Level (ELL) graph analysis, which starts with the assumption that there is a gap between CARL and UARL and uses leak detection cost data and the consumer cost of water to determine a theoretically ideal level of systemwide leak detection that will help drive real losses down, also typically indicates that system-wide leak detection is unwarranted. While such analysis results do not necessarily indicate that real loss cannot be further reduced – they do indicate that the utility should proceed with caution when it comes to expending resources on leak detection. With low levels of loss, a full-system leak detection may not be advisable from a purely economic standpoint because the cost of leak detection will likely significantly outweigh the value of loss reduction. There are, however, many other reasons to engage in targeted or system-wide leak detection including, but not limited to: • to establish a baseline ratio of detected vs undetected leaks in a system,

		• to hunt leaks in a known problem area • to verify that past repairs are holding, and • as a conservation effort where return on investment is not the primary driver. If the utility does engage in any level of leak detection, it should collect and maintain very detailed GIS records of leaks detected, leaks identified, and false positives, as well as time stamp data on when leaks are detected, when they are isolated, and when they are repaired as this data will be invaluable for future Leakage Component Analysis efforts.
Water Loss Control Program Recommendation	Main & Service Line Break Event Data	In order to calibrate and corroborate a water audit it is imperative that a utility be able to complete a bottom-up Leakage Component Analysis (LCA) using main and service line break data. Tracking such data in GIS is recommended, and break event attribute data should, at a minimum, include: • How the break was discovered • Date reported • Date isolated • Date repaired • Asset information (line material, size, condition, break type and dimension, local pressure, etc.) • Estimated volume lost • Cost of repair Collecting break data will allow LCAs to be completed for future audit years and will provide valuable insight regarding the condition of underground distribution main and service line assets.
Water Loss Control Program Recommendation	Flushing Volume Recapture	Well and water quality flushing can contribute significantly to non-revenue water, and flushing practices should be reviewed so that unnecessary losses can be mitigated. Determine how flushing volumes are disposed of (e.g., into storm sewer, into sanitary sewer, absorbed in settling ponds). Where feasible investigate whether currently lost volumes can be captured for possible re-use, either by

		diversion into a sanitary sewer for recapture or other method.
Water Loss Control Program Recommendation	Fire Department Flushing	Work with your local fire department to capture flushing volumes that result from hydrant exercising, as well as pressure and operational status information collected as part of their routine operations. If the utility uses a data collection application (e.g., SAMs, Fulcrum, Collector, etc.) consider training fire department staff in its use and providing data collection tools.
Water Loss Control Program Recommendation	Well Flushing	The SW EFC recommends that well flushing data be tracked together with the actual well production volumes and that these volumes be periodically reviewed and analyzed to ensure that well flushing cycles are optimized. If utility staff determine that the flushing volumes for one or more wells appear excessive, or insufficient, it is recommended that efforts be made to review individual well flushing cycles to ensure water quality is maintained while keeping flushing to the necessary minimum. Where flushing meters are taken out of service for repair, volumes should be estimated using "run time x flow" calculations and be included as unbilled unmetered volume or incorporated into the meter error correction.
Water Loss Control Program Recommendation	Customer Meter Testing	The SW EFC recommends that the utility conduct a cost-benefit analysis to determine whether to begin to proactively test statistically valid samples of its meter cohorts to determine optimal replacement cycles, or to continue replacing customer meters on a predetermined time or volume schedule. If a testing program is implemented, either in-house or using an outside contractor, low/mid/high and composite flow data should be documented and retained. This will allow the utility to more easily and accurately calculate flow weighted customer meter error correction factors for future water audits. This will also allow the utility to plot composite and individual flow level meter accuracy data to monitor meter

		deterioration and optimize meter replacement cycles for different meter cohorts in the system.
Program Management Recommendation	Asynchronous Communication Tools	Water loss auditing and water loss control programs function best as team-based endeavors. They also produce data and insight that should be maintained as institutional knowledge to facilitate ongoing improvements in auditing capabilities and loss control. However, facilitating the team-based approach can become difficult as water loss control team membership scales up to include all of the necessary personnel from across the utility. Further, critical institutional knowledge is often lost when personnel change positions within the utility or leave entirely. It is, therefore, recommended that where possible utilities leverage the capabilities of asynchronous communication platforms such as Microsoft Teams or Slack, to facilitate team communication and organize their water loss control program data and processes. Developing and communicating through a "Water Loss Control Team" channel in such a platform can, among other things: • reduce the need for in-person meetings while ensuring that necessary communication lines are maintained • promote transparency and communication within the team and larger organization while ensuring that critical communications are not lost • improve water loss control data organization; and • promote accountability for water audit and loss control related deliverables. Further, managing water loss control communications, data and other activities in this manner has the added benefit of creating a permanent, organized record of water loss control data, actions, successes and failures for posterity, ensuring that critical institutional knowledge is not lost when personnel change positions or leave the utility.

Table A-2: Sample Suggested Water Audit Timeline:

Time Frame	Audit Actions to be completed
Jan	Water Loss Control Team meeting to review Water Audit Guidance requirements and verify individual & department water audit data deliverables. Notify non-member staff of data needs.
Jan-Mar	Compile audit data for prior year: gather volume, source and consumption data; meter test data; billed and unbilled metered consumption; estimated consumption; main lengths and connections counts; financial data to calculate variable production and customer retail unit costs; review data for anomalies & draft memorandum noting any found and possible causes; summarize data by water audit input category
Feb	Begin component analysis - gather and begin analysis of the following data from prior year if available: leak detection data; main and service line break data, other real loss event data such as tank overflows
Mar	Water Loss Control Team meeting to review data inputs and anomaly reports; Complete and file AZ Lost and Unaccounted for Water Report; quarterly review of current year audit data and data collection activities; Verify that unmetered volumes are being tracked correctly
April - May	Compile Water Audit for Prior Year; Water Loss Control Team meeting to review audit results and address unforeseen issues; finalize any component analysis activities necessary to calibrate and/or confirm audit results
June	Validate and finalize prior year water audit internally; perform statistical analysis necessary to calibrate audit results and determine loss volume and KPI ranges; Water Loss Control Team meeting to review validated audit, address suggested improvement for following year and make any necessary revisions to Water Audit Guidance; communicate audit results to internal and external stakeholders; quarterly review of current year audit data and data collection activities; verify that unmetered volumes are being tracked correctly
July	Finalize documentation of recommended future changes to audit practices or procedures in Water Audit Guidance; draft and distribute any required SOPs, policies or procedures to implement change

Time Frame	Audit Actions to be completed
August	Verify consistent implementation of any new procedures; review status of any customer metering program in place; determine whether meter samples meet requirements; plan for any additional testing if necessary
September	Water Loss Control Meeting – Prior year audit debrief & begin planning for current year audit. Verify that documented procedural changes are being implemented. Quarterly review of current year audit data and data collection activities; verify that unmetered volumes are being tracked correctly
October	Verify source meter testing has been completed and that records are available for review (or schedule necessary testing);
December	Quarterly review of current year audit data and data collection activities; verify that unmetered volumes are being tracked correctly

Table A-3: Water Loss Switchboard Full Resource List

Category	Resource Title	Type
Getting Started	The Water Audit Handbook for Small Drinking Water Systems	pdf
	M36 Water Audits and Loss Control Programs (4th Edition)	Link to AWWA Resource
	GA Water System Audit and Water Loss Control Manual	pdf
	Texas Water Loss Manual	pdf
	An Introduction to Strategies to Address Real Water Losses Part 1	webinar
	Comprehensive Water Loss Control Program - Goal Setting Guide	pdf
	Water Audits and Water Loss Control for Public Water Systems	pdf
Audit Tool	AWWA Free Water Audit Software v5.0 (2014)	Link to AWWA Resource
	Data Validity Worksheet	spreadsheet
	Water Audit Data Grading Sheets	pdf
	Flow Weighted Average Tool	spreadsheet
	The Water Audit Handbook for Small Drinking Water Systems	pdf
	Level 1 Water Audit Validation: Guidance Manual	pdf
	Water Loss Audit	spreadsheet
	Customer Retail Unit Cost Calculation Tool	spreadsheet
Component Analysis	M6 Water Meters - Selection, Installation, Testing and Maintenance (5th Edition)	For Purchase
	Real Loss Component Analysis: A Tool for Economic Water Loss Control	pdf
	Leakage Component Analysis Model	spreadsheet

Category	Resource Title	Type
	Break Rate Index	Tool
Audit Results	Level 1 Water Audit Validation: Guidance Manual	Link to WRF resource
	Water Audit Validator Certificate Course Training Manual	pdf
	Validated Water Audit Data (2013) AWWA	spreadsheet
	Validated Water Audit Data (2014) AWWA	spreadsheet
	Validated Water Audit Data (2015) AWWA	spreadsheet
	Validated Water Audit Data (2011-2018) Georgia	Catalog of excel docs
	The State of Water Loss Control in Drinking Water Utilities	pdf
	Water Loss Auditing Navigating AWWA's Infrastructure Leakage Index	Webinar
Real Water Loss Control	AWWA Free Water Audit Software v5.0 (2014)	spreadsheet
	Real Loss Component Analysis: A Tool for Economic Water Loss Control	pdf
	Leak Repair Data Collection Guide	spreadsheet
	Leakage Component Analysis Model	spreadsheet
	Utilizing Smart Water Networks to Manage Pressure and Flow to Reduce Water Loss and Extend Useful Life of Pipes	pdf
	Guidance on Implementing an Effective Water Loss Control Plan - Report & Webcast	Webinar and report
	Break Rate Index	spreadsheet
	Water Loss Control Toolkit	pdf
	An Introduction to Strategies to Address Real Water Losses Part 3	webinar

Category	Resource Title	Type
	An Introduction to Strategies to Address Real Water Losses Part 2	webinar
	Asset Management Tools	website
	How to Save Water at Home	pdf
Apparent Water Loss Control	AWWA Free Water Audit Software v5.0 (2014)	spreadsheet
	M6 Water Meters - Selection, Installation, Testing and Maintenance (5th Edition)	For Purchase
	Guidance on Implementing an Effective Water Loss Control Plan - Report & Webcast	Webcast and Report
	Water Loss Control Toolkit	pdf
Presentations and Webinars	North American Water Loss Conference 2019	various
	Guidance on Implementing an Effective Water Loss Control Plan - Report & Webcast	webinar
	An Introduction to Strategies to Address Real Water Losses Part 3	webinar
	An Introduction to Strategies to Address Real Water Losses Part 2	webinar
	An Introduction to Strategies to Address Real Water Losses Part 1	webinar
	Water Loss Auditing Navigating AWWA's Infrastructure Leakage Index	webinar
Comprehensive Water Loss	M36 Water Audits and Loss Control Programs (4th Edition)	For Purchase
	Texas Water Loss Manual	pdf
	The Water Audit Handbook for Small Drinking Water Systems	pdf
	GA Water System Audit and Water Loss Control Manual	pdf
	Guidance on Implementing an Effective Water Loss Control Plan - Report & Webcast	Webcast and Report